National Aeronautics and Space Administration

Optical Measurement System for Strain Field Ahead of a Crack Tip for Lattice Structures

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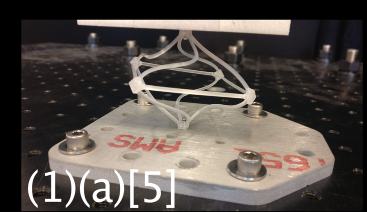
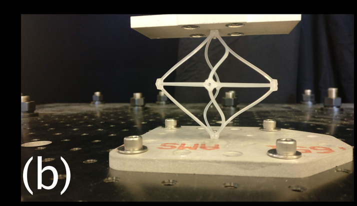
Introduction

The aim of the ARMADAS project is to automate the construction of cuboctahedral lattice structures.

- Lattice materials are appealing for aerospace applications due to their **strength and stiffness at ultra-light densities**.
- The material must also be **damage tolerant**.
  - The ability of a material to absorb damage is characterized by its **fracture toughness**, which remains poorly characterized for lattice materials.



(1)(a)[5]



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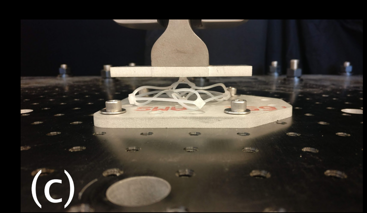
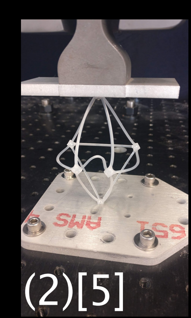


(c)

The objective of this research is to develop an optical measurement system to experimentally validate the strain field ahead of a crack tip in architecture lattice materials.

- We will use a **custom optical measurement** system to **track deformation** of the voxels in a side-cracked plate fracture specimen.



(2)[5]

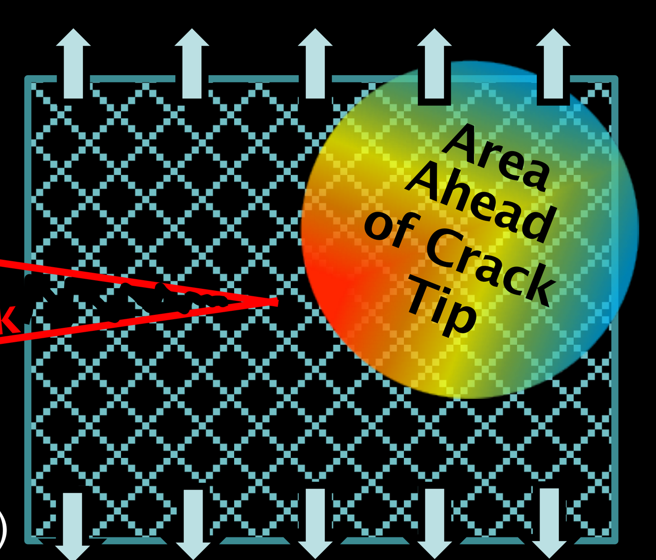
Objectives

I

Develop an optical measurement system to experimentally validate the strain field ahead of a crack tip in architecture lattice materials.

II

Wrap solution in a user-friendly interface which provides set-up instructions and precision estimates.



(3)

Methodology & Results

constraint

The stress-strain tests are conducted using the **Instron Bluehill3 machine and software** (Figure 4).

solution: All displacement measurements must be linked to Bluehill3's output data. The output data is in the form of a .csv (Figure 5a). A **parser**, written in Python 3, separates the metadata from the time, extension, and load data, and stores them in data structures (Figure 5b).

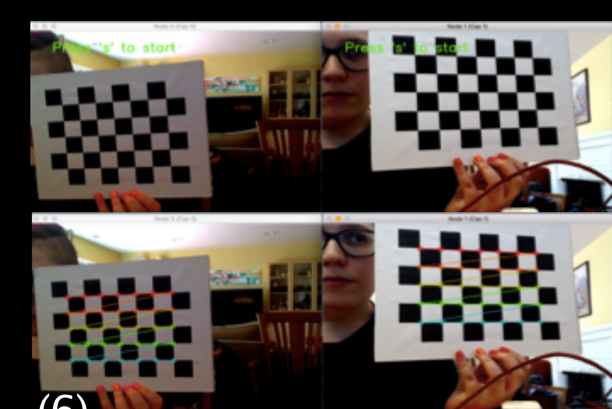
(4)

(5) (a) (b)

constraint

While undergoing the compression and uniaxial tensile tests, the nodes move in the **transverse, vertical, and sagittal axes.** Hence, one camera view is insufficient in tracking the nodal displacement

solution: Use **four (4) cameras** for stereo-imaging of the nodes. Figure 6 shows the stereo-calibration of two cameras using a chessboard pattern.



(6)

constraint

Video capture is an I/O bound process

solution: Move the I/O to a separate thread.

constraint

The Windows 7 box cannot be connected to the internet, thus making the time-syncing process for the multiple cameras trickier.

solution: Connect the Linux box (which can handle multiple video streams and will do the computational work) with the Windows 7 box using an ethernet switch and ethernet cables. Configure the Linux box as an NTP server and configure the NTP on the Windows 7 box to point to the IP address of the Linux box.

constraint:

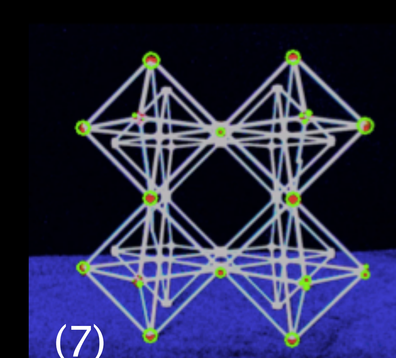
The Bluehill3 software only runs on Windows7

solution: Write a C# program to interface with the Bluehill 3's API, which send a signal to the Linux box to begin recording. This program will also continuously poll the Bluehill software for an end time.

requirement

Identify the front-facing nodes in such a way that they are trackable.

specification: Thus far, I have experimented with using color to identify the nodes. With the **color** properly identified, I can draw a contour around each node (Figure 7), thus **identifying the center point.**



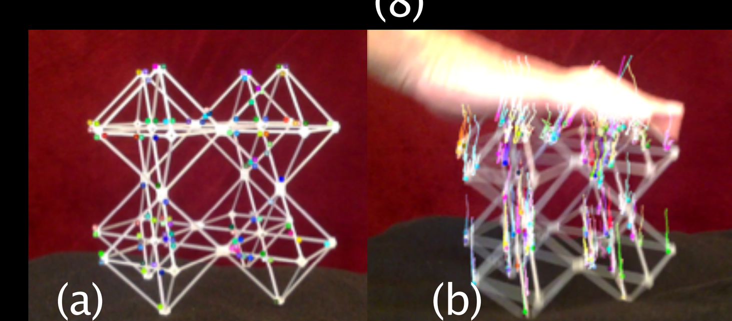
(7)

requirement

Detect the displacement of the lattice structure's nodes during a stress-strain test.

specification: Use OpenCV's Lucas-Kanade algorithms for optical flow analysis in combination with Martin Bloedorn's visual positioning system algorithms [1]. Store x, y, and z displacement in a data structure. Figure 8 shows the Shi-Tomasi Corner Detection (a) being used with optical flow (b).

(8)



(a) (b)

requirement:

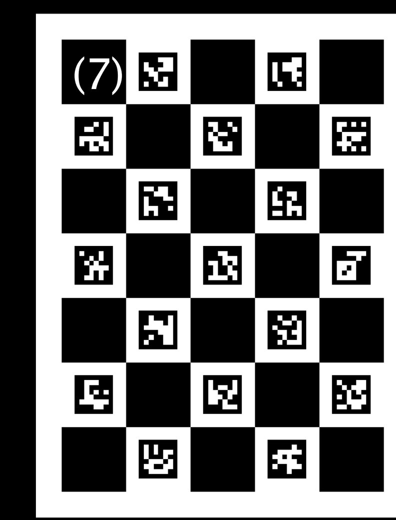
Make solution user-friendly.

specification: Identify nodes automatically (no clicking). Automatically synchronize the start of the Bluehill 3 software with the start of all video capture devices. All post-processing takes place automatically. GUI for set-up and calibration.

Future Work

Evaluate various methods of **increasing** both **accuracy and precision**:

- Use a **ChArUco board** (Figure 7), which is a board made up of fiducial markers and black squares, for calibration.
- Develop **user-friendly calibration** techniques
- Use **3D printed fiducial markers** that attach to the lattice nodes to improve tracking. An example of what these markers might look like can be seen in Figure 8.
- Use **a high-speed (1000-fps) camera**, to capture movement data at the millisecond level



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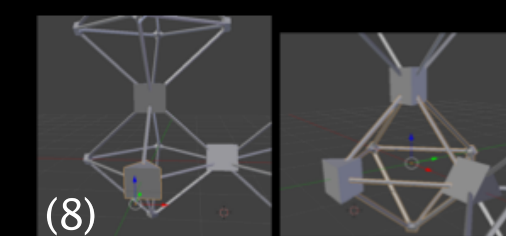
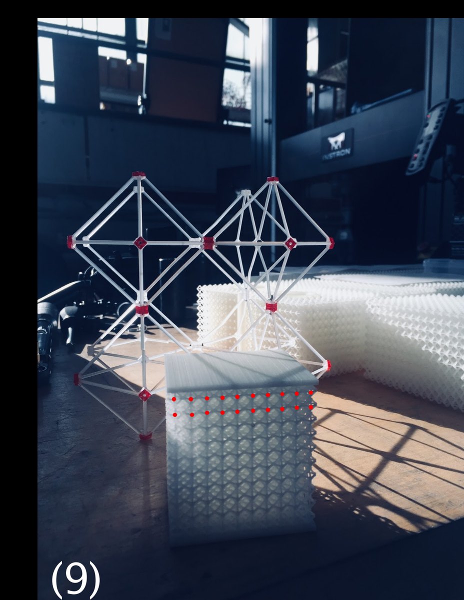


(8)

Ensure **scalability & robustness** of the solution:

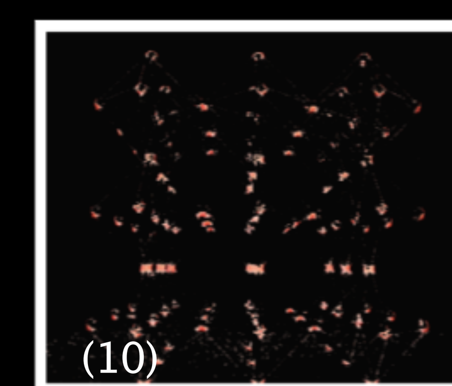
- Ensure the solution is fit for **smaller lattice structures.** Figure 9 shows an example of a smaller lattice structure and highlights some of the front-facing nodes which would be tracked.
- Ensure the solution is fit for much **larger structures**
- Ensure the solution is fit for various **geometries** and variety in **connections.**



(9)

Scale-up the solution:

- Be able to track **more** than just the front-facing **nodes.** Figure 10 shows a lattice structure with all nodes being detected using OpenCV's color detection algorithms.



(10)

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